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ABSTRACT

This paper, presented at the First National Conference of the New Zealand Association for Research in Education (NZARE), reviews science education research in New Zealand, 1970-1979. The reviews are considered under the following headings: (1) systematic effort to accumulate valid knowledge about science education aims, procedures, and outcomes; (2) inquiry into teaching conditions and learner factors influencing attainment in science; and (3) study of human learning in the context of science. It is indicated that the research papers and theses in science education have had little impact during the last decade and that any impact having occurred is possibly dependent as much on other factors as on the quality of the research. The paper presents criteria to produce worthwhile results of science education research which positively influence science teaching and learning, and some promising signs concerning the future of science education in New Zealand. (Author/SK)

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Science Education Research in New Zealand

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To review any area of endeavour it is first necessary to define the boundaries of the study. This is difficult to do for most subjects and research in science education is no exception. Whitfield (1979) considers it involves 'improving the quality and output of science education'. Kempa (1976) considers it is just 'research into the learning and teaching of science'. Renwick (1978) suggests simply that all educational research is concerned with finding answers to educational problems. But what are the problems of science education, specifically?

One of the difficulties with attempting to delimit science education research in New Zealand is that many of those working in this area are also involved with curriculum development work and/or are actively teaching science. Also, while many teachers would hesitate to say that they were undertaking science education research, the activities of some of them are virtually indistinguishable from the work done by education research students working in the field of science education.

For the purpose of this review, and with the above points in mind, science education research has been taken to be 'what people do when they are *primarily* concerned with *systematically* identifying and resolving problems in the teaching and learning of science'. This is

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perhaps a rather broad and generous definition but it is a view of science education research which needs to be taken if in fact such work is to be encouraged and developed, and is to be identifiable by science teachers as relevant to their concerns.

In terms of the above definition, science educational research is diverse. It includes:

1. Systematic effort aimed at the accumulation of valid knowledge about science education aims, procedures, and outcomes.

2. Inquiry into teaching conditions and other factors which may influence the attainment of educational aims in science.

3. The study of human learning as it is manifest in the context of science and in the institutional setting of science classrooms.

4. The study of the nature and place of science in the total curriculum from, for example, a philosophical or historical perspective.

In New Zealand work in this field is limited. Nevertheless, in the last 10 years almost 20 theses have been produced in New Zealand universities, in education and science departments, which could be considered to be in the field of science education research. Currently there are at least three doctoral students, as well as a number of masters students, involved in science education research. Numerous papers have appeared in the *New Zealand Science Teacher* which could be broadly classified in the field of science education research as well as occasional papers in other New Zealand educational journals (*New Zealand Journal of Educational Studies, Education, set* and so on).

Internationally, activities in the field of science education research are reported in journals such as *Science Education* and the *Journal of Research in Science Teaching* in the United States; *Studies in Science Education* and the *European Journal of Science Education* in the United Kingdom; and *Research in Science Education* in Australia. Contributions can also often be found in science teaching journals such as *School Science Review, Physics Education, Biological Education, Education in Chemistry* on the one hand, and in educational journals on the other, for example, *British Journal of Educational Psychology*. As evidenced by the papers cited in this review, contributions from New Zealand have appeared in a very large proportion of the above journals.

Science Education Research in New Zealand 1970-1979

In New Zealand universities there has been a slowly increasing awareness in science faculties of the legitimate place of science education research within science departments. For example the chemistry departments at Auckland, Massey, Victoria and Canterbury are active to some extent in chemical education research and the New Zealand Institute of Chemistry has had a regular Chemical Education Symposium as part of their yearly conference. Physics departments at Auckland, Waikato and also Otago have been active in the field of physics education research and the Institute of Physics in New Zealand holds regular symposia on Physics Education. Moreover, a few M.Sc. students working in university science departments have been involved in science education theses in recent years.

Education departments in New Zealand universities have produced the majority of theses in science education. In this regard Massey has been particularly productive. The theses cover diverse aspects of science teaching and learning. However, the number of published papers resulting from science education work in education departments seems to be limited. Sometimes the work is published in journals where it is less identifiable as science education research as such.

In recent years the appointment of people with backgrounds in science and education to the Higher Education Units at Auckland, Canterbury, Otago and Victoria has encouraged an interest in science education amongst science teaching staff at these universities (e.g., Peddie et al. 1977).

Many other science teachers, science advisers, teachers college lecturers and departmental officers have carried out small scale studies. In the main, these have been attempts, to find ways of assessing pupils, to gauge teacher opinion on syllabuses, to ascertain what units of work teachers teach where choice is allowed, and so on. Often those who have done this work have gained solutions to the particular problem of interest to them and have tended not to publish their work or alternatively have given brief details in the *New Zealand Science Teacher* or *National Education*.

A new development in science education research in New Zealand has been the sponsoring of science education research projects in universities by the New Zealand Department of Education. The *Interface Project* at

Auckland (Jones, 1979) and the *Learning in Science Project* at Waikato (Tasker, 1979) are two such projects which have brought together university people from education and science departments as well as departmental officers and teachers seconded from secondary schools. Other projects of this type are being planned.

To consider the work that has been done in the last 10 years in more detail, the four types of research activities detailed earlier in this paper will be used as a basis for categorization.

Systematic Effort to Accumulate Valid Knowledge About Science Education Aims, Procedures and Outcomes

It must be stated at the outset that a great deal of the work in this area has been somewhat less than systematic. Many of the references which will be cited are simply reports of new teaching methods which have been adopted with little more than subjective comment on their potential and their limitations. Nevertheless *collectively* these reports do provide accumulated knowledge about teaching and learning and for this reason they have a legitimate place in this review.

With respect to aims, the work of Duncan et al. (1971) is an example of a systematic attempt to gain views from a wide variety of people as to the desirable objectives of sixth form chemistry. Duncan et al. suggested that the relative importance of various chemistry objectives in the examination papers did not reflect the views of scientists and teachers. Teachers' views on the aims and content of various syllabuses have also been sought using questionnaires by Peddie (1976) who looked at chemistry at the secondary school level, Packer (1976) who investigated modular science proposals, and Petchell (1976) who sought information from Auckland schools on their views of the Form III and IV science syllabus. Although these studies are often very small scale, the influential position of those making such studies may mean that they do significantly influence future syllabuses. Petchell's study for the Auckland Science Teachers Association concluded 'that there would be very little evidence to support a major dismantling and rebuilding' of the Form III and IV science syllabus. Subsequent modification of the syllabus (Form I-IV draft syllabus, 1978) reflected that view.[1]

With regard to procedures there are many reports of new methods of teaching. The education symposia held at regular intervals by the Institute of Physics in New Zealand, and the New Zealand Institute of Chemistry are primarily concerned with communication of ideas about teaching - what is taught and how it is being taught - between Institute members teaching at the same level and at different levels of the educational system. These symposia reflect a general interest amongst teachers to learn what others are doing and this interest is reflected in the number of papers published in a variety of journals reporting on experiences with new syllabuses (Cosgrove, 1975; McGibbon, 1976; Hewson, 1978); new methods of laboratory teaching (Liley et al. 1976; Burns et al. 1979); and new methods introduced because of new educational technology (Penfold, 1976; Penfold, 1979; Osborne and Potter, 1979; Osborne, 1980; Pettigrew, 1979). Reports on the teaching of new content introduced because of new science (e.g., Earnshaw, 1974; Hodgkinson, 1978) or new societal trends (e.g., Callaghan and Jones, 1979) can also be found. Reports of the novel use of various methods of teaching at a particular age level are also common: project work (Lockett, 1974; Shaw, 1976; Lockett, 1977); contracting (McGrath, 1975; Francis, 1975) and team teaching (Jowett, 1976). Reports can also be found of attempts to teach objectives not normally taught (Norris, 1976).

While the above reports collectively give some indications of methods being used in classrooms to teach science, there appears to be a lack of reports which give some overall perspective of the teaching and learning practices in schools. McMurray (1971) used a questionnaire to show teachers were facing difficulties in implementing the then new Form I science syllabus. Julian et al. (1979), using a questionnaire, investigated class size, the proportion of teaching time spent in laboratories, the qualification of technicians, and finance in secondary school science departments. Earlier Osborne (1973) had investigated the number of graduates in chemistry, physics, biology and mathematics in New Zealand secondary schools. Hitchings (1975a) and Peddie (1976) have both investigated chemistry teachers' views on in-service training. While all these reports are based on the premise that effective teaching depends on good resources and well qualified teachers, the typical teaching

methods and learning procedures used in schools remain largely undocumented. However, the recent work of Jones (1979) with respect to Form VII and first year university physics and Tasker (1979) with respect to Form I-IV science are examples of attempts to rectify this deficiency.[2] Munro's work (Munro, 1976) in sensitizing teachers to what is going on in their own classrooms should also be mentioned here.

With regard to outcomes, the simplest outcome to measure is the number of students taking the subject at various age levels. Osborne (1973), Neilson (1974) and Strachan (1974) have detailed some aspects of enrolments in science. The Department of Education monitor enrolment trends but their actual figures are rarely published in a way that trends can be easily discerned. Examinations achievement can also be documented. Mitchell (1971) investigated the pass-fail criterion as it operated in the end-of-year examinations of the University of Otago over nineteen years. His results include science and raise questions of validity and reliability of university examinations. Comber and Keeves (1973) compared aspects of achievement in secondary school science in 19 countries including New Zealand. Putt (1978) has compared the grades in first year physics at Auckland University, Melbourne University and some universities in the USA using common examination questions. Peddie and White (1975) investigated the reliability of first year chemistry examinations at the University of Auckland, their results suggesting one reason why university success is so difficult to predict. Putt (1979) has investigated the effect of time restrictions on students' exam performance.

Outcomes other than overall achievement in a subject have also been studied. Osborne (1979) investigated the ability in basic mathematics of matriculating physics students using a criteria-based test. The attainment of particular course objectives has been investigated by Gibbs (1978) with respect to sixth form chemistry and Osborne (1978) with respect to first year physics. Novel techniques for the measurement of various objectives have also been developed. McGrath (1973) developed a test to investigate skills and processes in Form III and IV science. Osborne (1977) investigated the subjective assessment of student profiles in physics.

In reviewing this work on 'aims, procedures and outcomes' over the last ten years what overall comment can be made?

1. With respect to aims, Duncan's study (Duncan *et al.*, 1971) is unique in seeking comment about curricular objectives from several sections of the community. The authors stated: 'one hopes that the conclusions drawn and methods used are sufficiently interesting for others to undertake similar work in the areas with which they are specifically concerned'. In my view it is a pity that this challenge has not been taken up, not least because the deciding of aims for our curricula is an important and central issue.

2. With respect to procedures, this is an area of great interest to teachers and many papers have been published. However almost all of the papers on innovations have been authored by someone involved in the innovation. What is desperately needed, I believe, is *independent* appraisals which carefully document what is happening and give a detailed analysis of the perceived potential and limitations of the innovative procedures. Careful documentation is also needed about what is going on in typical science classrooms. Such work, I would suggest, would engender worthwhile soul-searching amongst teachers and curriculum developers and provide a firm base on which to build more contrived research studies.

3. With regard to outcomes, the development of valid and reliable assessment procedures to measure pupil attainment with respect to the breadth of the objectives of today's science courses is of major importance. Despite the work done much more needs to be done in this area. Assessment is the tail that wags the dog at all levels of science teaching.

Inquiry into Teaching Conditions and Learner Factors Influencing Attainment in Science

With respect to investigating the teaching conditions influencing attainment of educational aims in science, Flynn and Munro (1970) compared Nuffield science teaching with more traditional methods. With respect to the objectives they measured, which were indeed objectives of the

Nuffield course, those children who had been taught Nuffield did show significantly more growth on the objectives measured than the control group. However they are cautious in their conclusions commenting on possible Hawthorne effects and the teamwork of the teachers in the experimental schools 'could have been more important than course materials'. More recently, Putt (1977) and Longbottom (1979) have investigated the effectiveness of individualised instruction, in university physics and Form IV science, respectively. In addition the *Interface Project* (Jones, 1979) and the *Learning in Science Project* (Tasker, 1979) although not comparative studies and less formal than the above studies, are centrally concerned with the teaching and learning conditions influencing attainment of educational aims in science.

A large number of psychometric studies have been concerned with learner factors and influence of these factors on various aspects of attainment. With regard to cognitive attainment, Marsh (1970) investigated the degree to which pre-entry factors were associated with the outcome of their first year examinations. The students studied formed almost half of the 1968 intake to Victoria University and included science students. Osborne (1976) and Peddie et al. (1977) have carried out similar studies for first year physics and chemistry respectively. At the secondary school level the IEA study (Comber and Keeves, 1975) investigated science in New Zealand schools along with science education in 18 other countries. Other small scale psychometric studies have attempted to establish factors influencing the following: application of knowledge (Okech, 1971); vocabulary in science (Connors, 1972); aptitudes (Cookson, 1975); attitudes (Thomas, 1976); and interests in science (Lai, 1977). Many of these studies are limited in that the learning experiences of the children are largely undocumented or even unknown, and the validity of the tests developed as part of these studies is often unstated.

In reviewing this aspect of science education research over the last 10 years I personally consider that the psychometric studies have not had the impact on teaching that was hoped for. It is difficult for the statistical models to represent the complexity of the teaching and learning situation, it is difficult to identify and measure all important variables, and the findings are not easily related to how teaching and learning should be modified. As suggested earlier what seems to be lacking, at least in part, is a firm base on which to build these studies. The careful documentation of what goes on in classrooms and what goes on in the home (e.g., Davis, 1979)

may lead to the development of significant hypotheses about teaching and learning and the identification of significant variables. To my mind what we have learnt with regard to this aspect of science education research in the last 10 years is that we must first learn to walk before we can run.

Study of Human Learning in the Context of Science

McAlpine's study of open-ended thinking with pupils of high ability in science (McAlpine, 1971) is an example of a study of human learning in the context of science. Aspects of the work in the *Learning in Science Project* concerned with children's meanings for words used in science and children's views of the world (Stead and Osborne, 1979) might also be classified in this category.

While there are few New Zealand studies which are most appropriately categorized under this heading, overseas research would suggest that science is a fruitful area in which to study cognitive development. Many overseas researchers in this area have a background in science education and recent work, for example, papers from the Cognitive Development Research Seminar, Leeds, September, 1979, suggests that ideographic studies, based on exploring the learner's world, will be a major area of study in the 1980's.

Study of the Nature and Place of Science in the Curriculum

The study of the nature and place of science in the curriculum, from philosophical and historical perspectives, provides a further essential component to science education research. Such analyses can give new insights into what should be taught and learnt, and what logical difficulties are associated with what teachers are attempting. Such studies also provide opportunities to learn from the past.

With regard to the philosophical perspective, Neilson (1974) considered biological education in New Zealand schools. He analyzed trends in teaching and questioned what he perceived as a move by curriculum developers and textbook writers toward quantification, reductionism and factualism. In the light of this analysis he proposed some alternative goals. Burkin (1976) has considered the relationship between new syllabus goals, what is appropriate for most children, and what is

actually taught in schools. Bagnall (1979) has considered the nature of science and the needs of adults with respect to education in the sciences. Earlier, Peddie (1973) made a critical examination of the objectives of the school science syllabus, while Greening (1976) considered the various teaching methods applicable to microbiology teaching.

A number of short papers in the *New Zealand Science Teacher* could also be included here. For example, Walker (1973) has considered the problems of the lower ability pupil doing science. Vincent (1978) provided an analysis of laboratory activities, while Fletcher (1979) considered whether or not the present teaching is nurturing scientists or conformists.

From an historical perspective Barton (1974) has compared science and chemistry teaching in New Zealand since 1940, with trends in the USSR, UK and USA. Hitchings (1975) has considered chemistry in New Zealand and also (Hitchings, 1978) reviewed science teaching in New Zealand from 1958-1977. Malcolm (1979) has explored the trends in science education over the last three decades as well as considered the relationship between views on the nature of science and science teaching. There has not been a large number of studies in this field in the last 10 years and possibly science teachers, in particular, undervalue such studies. However so long as objectives and teaching continue to undergo change, teachers and curriculum developers need to see what they are doing in a broad philosophical and historical perspective. For this reason, therefore, I believe further studies in this area are important. Consider, for example, how many teachers were able to judge the innovative Keller Plan (PSI) more rationally on learning it was very similar to the Dalton Plan of the 1920s?

Conclusion

This review shows that a number of research papers and theses on science education have been written during the last decade. However what impact has this work had on the teaching and learning of science in New Zealand? I would consider the impact is very small indeed and any that has occurred is possibly dependent as much on other factors as on the quality of the research; for example acceptability of findings, status of the researcher, dissemination of the findings, and so on. Much of the research has unfortunately been small scale, short term and done by individuals working in isolation for a specific purpose, for example to gain evidence to support a viewpoint or to gain a degree.

In terms of overseas experience what is required if science education research in New Zealand is to produce worthwhile results, and positively influence science teaching and learning, is:

1. Sustained team effort where expertise and experience is built up over a period of time. The backgrounds of those in the team must be diverse, but as Fensham (1976) implies an essential requirement for the majority of team members is a good background in science, preferably with at least thesis research experience, as well as considerable teaching experience and expertise. The development of such team work requires a commitment by all sectors of education (e.g., New Zealand Department of Education, the universities) to science education research.

2. Increased identification with, and involvement in, science education research by teachers of science at all levels, but particularly by university science teachers who have, as Hestenes (1979) suggests, considerable influence on science teaching at all levels, for example, through the training of future science teachers, influence on syllabuses, textbook writing and so on. Hestenes makes the comment that at least in the USA:

> Science education specialists are located in schools of education so that they are cut off from the well-spring of their discipline, the various scientific disciplines themselves. Consequently their research suffers in quality and is limited primarily to the teaching of science to young children. Science education will not come of age until it is recognized and actively supported in the universities by departments of physics, chemistry and biology and mathematics. (Hestenes, 1979, p.240)

3. A firm link to the various disciplines of education to ensure that the learner and teacher, rather than the science, is of central concern.

What then of the future of science education research in New Zealand? There are signs that are promising:

1. The collaborative ventures of universities and the New Zealand Department of Education through the sponsoring of science education research (for example the *Interface* and *Learning in*

Science projects) and the sustained team work that this is encouraging.

2. The increasing interest by science teachers in science education research as evidenced by papers in the *New Zealand Science Teachers Journal* and the proposed science education research section in the New Zealand Science Teachers Association Conference in 1980.

3. The number of people in New Zealand university science departments who are interested in science education research (20 such people are referenced as authors in this review).

4. The possibilities offered by conferences such as this one to establish links with others interested in the field and thereby encourage a community of people involved in science education research who can feel they can openly share ideas and problems through correspondence, sharing of working papers and conferences.

The Australian Science Education Research Association has grown from tentative beginnings ten years ago to a healthy community of researchers in 1979. What Australia could do in the 70s, surely we can do in the 80s.

Footnotes

1. The draft syllabus specifically refers to Petchell's survey.

2. Fensham (1976) has pointed out the need for such work:

> Much contemporary research in chemistry and physics is still the careful systematic reporting of the properties of substances and phenomena. A very large amount of this must occur before hypotheses of significance can be formulated and put to empirical test. Many workers in educational research seem to feel that such a phase is not enough and rush into hypothesis construction and testing. This leads to data which are consistent with trivial hypotheses... or non significant results - the interpretation of which is again often confused. (p.108)

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